Spectral control of thermal emission or absorption plays a crucial role in efficient thermal energy harvesting and radiative cooling, while near-field effect between objects within subwavelength vacuum distances could greatly enhance radiative heat transfer beyond blackbody limit for augmented heat flux and power density. In this talk, I will mainly discuss our recent experimental progresses in highly-efficient solar thermal energy conversion, dynamic radiative thermal control, and super-Planckian near-field radiative heat transfer. In particular, nanostructured metamaterial selective absorbers were fabricated and temperature-dependent optical and infrared radiative properties were characterized. Large-area metafilm absorber with excellent spectral selectivity and high-temperature stability was experimentally demonstrated to enhance solar-to-heat conversion at multiple suns, while its impact on solar thermophotovoltaic conversion was theoretically predicted. For dynamic radiative thermal control, thermochromic VO₂ based metafilm structure was developed, whose infrared emissivity increases significantly for enhanced radiative cooling when it is above phase transition temperature. A vacuum thermal measurement was performed to demonstrate how the tunable VO₂ metafilm modulates radiative heat flux with temperature. On the other hand, a tunable metamaterial with patterned Al gratings on VO₂ thin film exhibits an opposite behavior with lower infrared emissivity when VO₂ is metallic at high temperatures, indicating thermal runaway. To experimentally demonstrate near-field thermal radiation, we used polystyrene nanoparticles as spacers between two 5 × 5 mm² Al-coated silicon chips to achieve vacuum gap of 215 nm, at which radiative heat flux between nanometric Al films was measured to be 7.4 times over blackbody limit or by 480 times compared to far-field radiative heat transfer between metallic surfaces. In another work, SU8 polymer microposts with different heights were fabricated to directly create nanometric vacuum gaps which were precisely determined by in-situ capacitance measurements. The near-field thermal radiation between two 1 × 1 cm² heavily-doped silicon chips was measured to be 11 times over the blackbody limit at 190 nm gap. Finally, designs of near-field thermal rectifier, thermal switch and thermal modulator will be proposed, and future near-field experiments will be briefly described.